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(54) Optical film material of a metal oxide

(57) Optical film material of a metal oxide is deposited by reactive magnetic field enhanced DC-sputtering from a metallic target and has optical losses of 15dB/cm at the most for a wave-length of light of 633nm. Specific oxides deposited are TiO_2 and Ta_2O_5. TiO_2 has for a wave-length of light of 633nm optical losses of 1.5dB/cm at the most, preferably open 0.7dB/cm at the most, preferably 0.3dB/cm at the most. Ta_2O_5 has for light of the wave-length of 633nm optical losses of 3dB/cm at the most, preferably 1.5dB/cm, preferably 0.7dB/cm at the most, preferably 0.3dB/cm at the most. The optical layer is made of optical layer material of a metal oxide deposited by reactive magnetic field enhanced DC-sputtering of a metallic target and having optical losses of 15dB/cm at the most for light of wave-length of 633nm. The method for producing a layer of a metal oxide with optical losses of 15dB/cm at the most for light with a wave-length of 633nm, comprises magnetic field enhanced reactive DC-sputtering of the said layer. This sputtering may be performed with a process working point in the transition mode between the metallic mode and the oxidic mode. The optical film material may be used to produce an optical waveguide.

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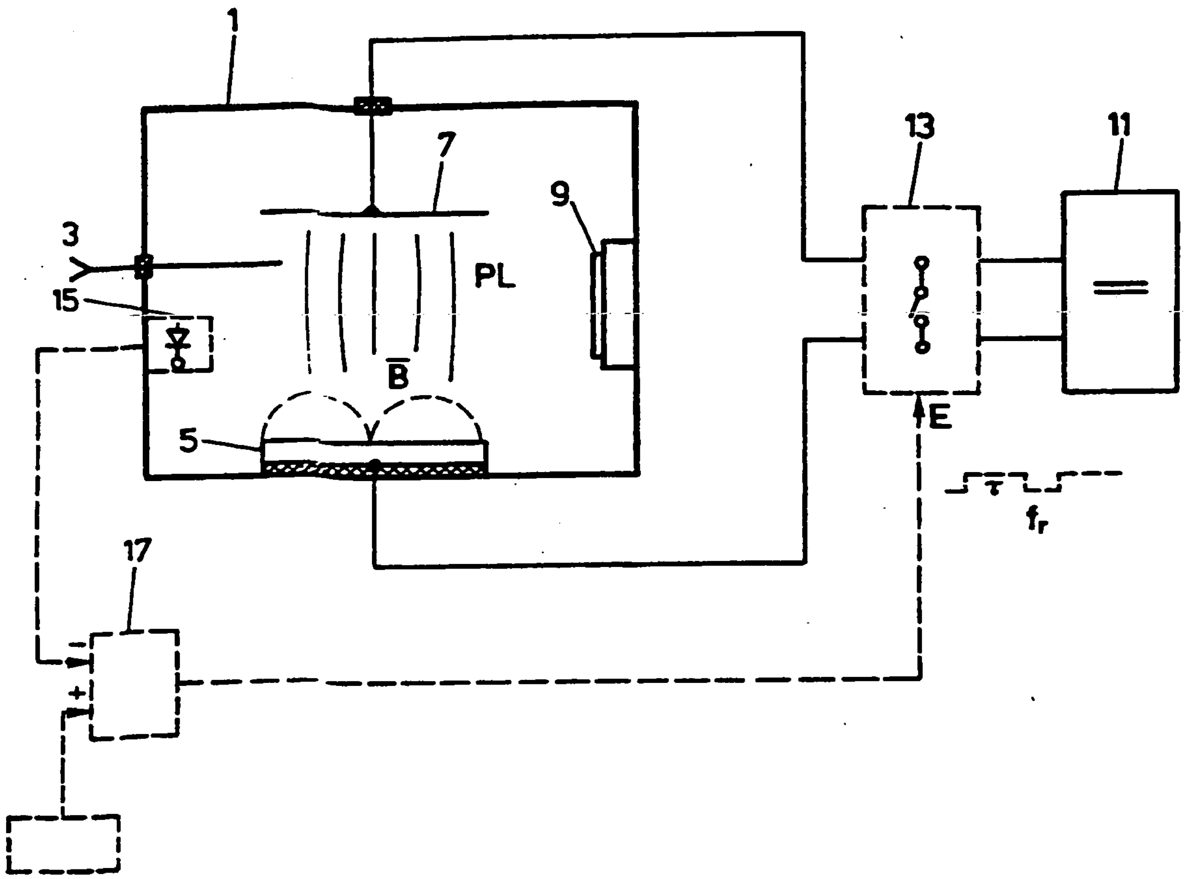

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Optical film material, especially TiO_2 or Ta_2O_5, optical waveguide layer and method for producing such

Background of the invention

Field of the invention

The present invention is generally directed to optical layer materials, especially for optical waveguide applications, and to the technique of producing such layers.

Description of prior art

The following prior art is considered:

(1) "Integrated Optics: Theory and Technology", R.G. Hunsperger, Springer-Verlag 1984;

(2) Arnold et al., "Thin solid films", 165, (1988), p. 1 to 9, "Ion beam sputter deposition of low loss Al_2O_3 films for integrated optics";

(3) Goell & Stanley, "Sputtered Glass Waveguides for Integrated Optical Circuits", in Bell Syst. Tech. J. 48, 3445 (1969);

(4) M.D. Himel et al., "IEEE Photonics Technology Letters" 3(10), (1991), p. 921 ff.;

(5) C. Henry et al., Appl. Optics, 26(13), 1987, 2621, "Low Loss $Si_3N_4 \cdot SiO_2$ Optical Waveguides on Si";

(6) J.Appl.Phys. 71(9), (1992), p. 4136, Gräupner et al.;

(7) DE-A-41 37 606;

(8) "Plasma-Impulse CVD Deposited TiO_2 Waveguiding Films: Properties and Potential Applications in Integrated Optical Sensor Systems", Mat.Res.Soc., Spring Meeting San Francisco, 1992, Conference publication;

(9) "Magnetron sputtering deposited AlN waveguides: Effect of the structure on optical properties", A. Cachard et al., Vacuum 41/numbers 4-6/p. 1151 to 1153/1990;

(10) Applied Optics, Vol. 14, No. 9, September 1975, New York, US, p. 2194-2198, Ingrey et al., "Variable Refractive Index and Birefringent Waveguides by Sputtering Tantalum in O2/N2 Mixtures";

(11) Journal of Vacuum Science and Technology, Vol. 11, No. 1, January 1974, New York, US, p. 381-384, Westwood et al., "Effect of Pressure on the Properties of Reactively Sputtered Ta2O5";

(12) Journal of Electronic Materials, Vol. 3, No. 1, 1974, US, p. 37-50, Cheng et al., "Losses in Tantalum Pentoxide Waveguides";

(13) Proceedings of the Spie: Hard Materials in Optics, Vol. 1275, March 14, 1990, The Hague, NL, p. 75-79, Howson et al., "The Reactive Sputtering of Hard Optical Films of Tin Oxide";

(14) Journal of Vacuum Science and Technology: Part A, Vol. 2, No. 2, April 1984, New York US, p. 1457-1460, Demiront et al., "Effects of Oxygen in Ion/Beam Sputter Deposition of Titanium Oxides";

(15) Surface and Coatings Technology, Vol. 49, No. 1-3, December 10, 1991, Lausanne, p. 239-243, Martin et al., "Deposition of TiN, TiC, and TiO2 Films by Filtered Arc Evaporation".

It is known from (9) to deposit metal nitride layers or films by means of reactive DC-sputtering, namely layers of AlN. As optical waveguiding layers such layers are reported to have optical losses of about 11dB/cm at minimum, at a wave-length of light of 633nm and in the TE_0-mode. Such layers are also reported to show optical losses down to 5dB/cm.

It is known from (4) to manufacture TiO_2 which, applied as material of a waveguiding layer, exhibits optical losses lower than 10dB/cm. Thereby it is not specified for which wave-mode and for which wave-length of light such losses are valid. From this reference it is further known to apply Ta_2O_5 for waveguiding layers which exhibit optical losses of less than 5dB/cm, which losses are again neither specified with respect to wave-lengths of light nor with respect to propagation mode. The layers are here produced by an ion plating technique.

In agreement with the contents of (4), even in the year 1991, the reference (7) teaches that TiO_2 would be most suited as a material to produce thin film optical waveguides due to its physical and chemical properties. In spite of titanium oxide exhibiting a very high index of refraction, a good chemical resistance and being very hard, it is reported that no method had been known in the literature for producing a low loss titanium oxide thin film waveguide, because of the fact that titanium oxide exhibits a high tendency to cristallization during manufacturing.

Therefore the reference (7) proposes to deposit TiO_2 as a

material suited as optical waveguiding material by means of a pulsed micro-wave plasma CVD-method. Applied as material for waveguiding purpose, the TiO_2 produced by the method proposed in (7) exhibits for TE_{01}-waves of not specified wave-length, optical losses of about 2,5dB/cm.

With respect to wave-lengths it is principally valid that the optical losses become the larger, the shorter the wave-length is selected.

From the reference (2) it is further known to produce Al_2O_3-layers by ion beam sputtering exhibiting low optical losses, lower than 1dB/cm at a not specified propagation mode and a not specified wave-length of light. Due to the proposed ion beam technology, the proposed manufacturing method is not suited for large areal coating and exhibits a relatively low coating rate. This in combination results in an accordingly uneconomic layer production.

The reference (3) proposes to use as a material for optical waveguiding layers Rf-sputtered glass. The reference (5) further proposes to produce a material which is suited for waveguiding applications by means of low pressure plasma CVD followed by a heat treatment annealing step.

The reference (8) further proposes to produce TiO_2 by means of plasma impulse CVD, which material, applied for monomode waveguiding in the TE_0-mode, exhibits optical losses of 2,4dB/cm or of 5,1dB/cm in the TM_0-mode, each referred to the wave-length of light of 633nm.

In spite of the knowledge out of reference (9), the reference (6) still describes that reactive sputtering of metal nitride layers, namely of AlN, from a metallic target results in

layers which, applied as optical waveguiding layers, exhibit very high optical losses of 300dB/cm at propagation conditions which are not specified. Such a material is, in fact, not any more an optical layer material due to its extremely high optical losses and may especially not be said to be suited for optical waveguiding.

Such as the TiO_2 referred to in reference (7), other metal oxides would be suited as optical layer material, whereby known methods for producing layers of such materials, as e.g. ion beam sputtering according to reference (2), micro-wave plasma CVD according to reference (7), plasma impulse CVD according to reference (8), low pressure plasma CVD according to reference (5) or ion plating methods according to (4), are disadvantageous especially with respect to large areal coating and deposition rate, so that the wide-spread production of such layer materials is very difficult to reduce to practice in a commercially feasible manner.

The recognition published in reference (7), according to which TiO_2 has the tendency of cristallization during its production, is made, with respect to tantalum pentoxide, in reference (10), i.e. in the year 1975. According to (10), already in that year, reactive DC-diode sputtered optical waveguiding layers were proposed, sputtered in N_2- and O_2-gas mixture atmosphere, thus, in fact, some sort of tantalum oxinitride layers.

For deposition rates of approx. 0,4Å/sec and at temperatures of about 200°C, there are reported optical losses in the TE_0- and the TM_0-modes, lower than or equal to 1dB/cm at a wavelength of light of approx. 633nm. Such results are attributed to the nitride addition to the sputtering atmosphere.

From the reference (11) of 1974, which is referred to in reference (10), it is known to produce Ta_2O_5-layers for thin film capacitors and for optical waveguides by means of reactive DC-diode sputtering in an O_2/Argon atmosphere. Different sputtering parameters are varied and losses of approx. 1dB/cm are reported from the best layers thus produced. Thereby, the following dependencies are reported:

With rising sputtering pressure:

- increase of the optical losses;
- increase of coating rate;
- reduction of coating temperature.

The temperatures reported in reference (11) are in a range between 160°C and 350°C at lower pressure of approx. $1,6 \cdot 10^{-2}$mbar operating pressure and are about 180°C at higher operating pressure of about $8 \cdot 10^{-2}$mbar.

In reference (12), which is referred to in (10) as well as in (11) and which has in parts the same authors, comparisons are made between Ta_2O_5-layers produced by different methods, so e.g. deposited by reactive DC-sputtering or by metallic sputtering with thermal post oxidation at temperatures of between 550°C and 650°C. For Ta_2O_5-layers deposited by reactive DC-sputtering, optical losses between 1 and 6dB/cm are reported for the TE_0-mode, such layers being produced at a deposition rate of approx. 0,12Å/sec and at deposition temperatures of 200°C.

In combining the references (12) up to (10), there may be seen the tendency of leaving the approach of manufacturing low loss

tantalum pentoxide layers and trying to manufacture such layers rather from Tantaloxinitride, deposited by reactive diode-DC-sputtering at relatively low deposition rates and at relatively high deposition temperatures.

The reference (13) further describes production of SnO_2-layers by DC-sputtering. The measuring results published in this reference lead to the conclusion that the optical losses will be in the range of $3 \cdot 10^4$dB/cm.

From (14) it is further known to produce TiO_2-layers by means of ion beam sputtering. A rough estimate of the optical losses from the published measuring results leads to such losses in the range of 400dB/cm.

Finally, the reference (15) describes to produce TiN-, TiC- and TiO_2-layers by means of arc evaporation. From the extinction coefficient which is reported for TiO_2-layer material of 0,07 at a wave-length of 633nm, very high optical losses may be expected.

Summary of the invention

It is a first object of the present invention to provide a material for optical layers of a metal oxide, production of which may be significantly less expensive, which exhibits low optical losses, which further may be produced at lower temperatures compared with temperatures at which such known layer materials are produced.

This object is realized by an optical film material of a metal oxide being deposited by reactive magnetic field enhanced DC-sputtering from a metallic target and having optical losses of 15dB/cm at the most for a wave-length of light of 633nm.

By reactive magnetic field enhanced DC-sputtering, the expected low optical losses are maintained and, additionally, high deposition rates at low deposition temperatures are reached. Under the expression "magnetic field enhanced sputtering" all DC-sputtering techniques shall be understood, at which lines of magnetic flux are generated, which loop in a tunnel-like pattern across the target surface and/or which loop from the target surface to neighbouring parts of a processing chamber. An especially preferred example of such magnetic field enhanced DC-sputter techniques is magnetron DC-sputtering.

It is a further object of the present invention to provide such optical layer material of further reduced optical losses, which is realized by reducing the optical losses mentioned to 4dB/cm at the most.

It is a further object of the present invention to provide said optical film material with high chemical resistance and with high hardness, which object is achieved by the optical film material mentioned above, being TiO_2, with even further reduced losses of 1,5dB/cm at the most.

The last mentioned object of the present invention is further realized, too, by providing the optical film material mentioned, as tantalum pentoxide, with reduced optical losses of 3dB/cm at the most.

It is a further object to provide the optical film material of metal oxide mentioned above with even further reduced losses, which is realized by such a material having optical losses at the wave-length mentioned of 1,5dB/cm at the most.

Following the further object to even further reduce the optical losses as specified, it is proposed to provide the optical

film material of metal oxide with optical losses of 0,7dB/cm at the most or even of 0,3dB/cm at the most.

It is a further object of the present invention to propose the mentioned optical film material so that it may be produced in a controlled process in the sense that arcing, as may occur in reactive DC-sputter deposition of metal oxide, may strictly be maintained under control. This object is realized by the mentioned optical film material being deposited by time-intermittent reactive magnetic field enhanced DC-sputtering.

It is a further object of the present invention to provide an optical film material as mentioned above which is produced economically, which is resolved by the material of the inventive optical film being deposited with a deposition rate of 0,5Å/sec at the minimum and even with a deposition rate of 0,9Å/sec at the minimum.

It is a further object of the present invention to propose an optical film material which is deposited so that e.g. a substrate, whereon it is deposited, is not affected by the deposition process. This object is realized by such material being subjected to a deposition temperature of 150°C at the most and even to a deposition temperature of 100°C at the most and, in a further improved embodiment, to a deposition temperature of 70°C at the most.

It is a further object of the present invention to provide TiO_2-material exhibiting very low optical losses, which object is realized by TiO_2 having optical losses of 1,5dB/cm at the most for a wave-length of light of 633nm. Thereby, an even improved TiO_2 exhibits optical losses at the said wave-length of light of 0,7dB/cm at the most and even of 0,3dB/cm at the most.

It is a further object of the present invention to provide a Ta_2O_5-material with optimized optical losses, which is realized by Ta_2O_5 wherein the optical losses for light of the wave-length of 633nm are 3dB/cm at the most.

Thereby, an even further improved Ta_2O_5 is proposed, wherein the optical losses specified above are 1,5dB/cm at the most or even in a further improved material are 0,7dB/cm or even 0,3dB/cm at the most.

It is a further object of the present invention to provide an optical layer which is produced in an economically satisfying manner and is thus producible on a large scale. This object is achieved by an optical layer made of an optical layer material of a metal oxide, being deposited by reactive magnetic field enhanced DC-sputtering of a metallic target and having optical losses of 15dB/cm at the most for light of the wave-length of 633nm.

The object of even further reducing the optical losses of such optical layers is achieved by providing TiO_2 as layer material with optical losses being 1,5dB/cm at the most or even being 0,7dB/cm at the most.

Following the object of further improving the optical layer mentioned above and providing for a further layer material to that target, said optical layer of tantalum pentoxide is proposed with optical losses of 3dB/cm at the most or even with such losses of 0,7dB/cm at the most.

It is a further object of the present invention to construe by means of the optical layer mentioned above an optical multi-layer system. This is realized by the optical layer mentioned above within an optical multi-layer with at least

one optical layer of lower refractive index material and at least one optical layer of higher refractive index material, whereby the optical layer which is deposited by reactive magnetic field enhanced DC-sputtering is the higher refractive index material layer.

It is a further object of the present invention to provide the optical layer mentioned above as an optical waveguiding layer which is achieved by that optical layer, being an optical waveguiding layer with the low optical losses specified above, being valid in a TM-monomode, especially in the TM_0-mode.

In a preferred embodiment for a large number of applications, the inventive optical layer is a substantially flat optical waveguiding layer.

It is a further object of the present invention to propose a method for producing a layer of a metaloxide resulting in economic production of such layers and in layers with low optical losses. This is realized by a method for producing a layer of metaloxide with optical losses of 15dB/cm at the most for light of a wave-length of 633nm, which method comprises magnetic field enhanced reactive DC-sputter deposition of the layer.

In a first preferred way of execution, the inventive method is performed by the mentioned sputtering realized in the oxide mode. To fulfil the object of further optimizing the inventive method of production, performing the reactive magnetic field enhanced DC-sputtering, is made in the instable transition mode (between metallic mode and oxide mode) and the transition mode of processing is stabilized to lead to a stable processing working point.

Thereby, it is further proposed to perform the magnetic field enhanced reactive DC-sputtering in a time-intermittent manner, preferably in a time-intermittent manner at a frequency of 30kHz at the most and in a further preferred manner at a frequency of 20kHz at the most.

All magnetic field enhanced reactive DC-sputtering mentioned up to now is preferably performed as magnetron sputtering.

Further objects and their solutions will become apparent to the man skilled in the art by the wording of the claims and of the following description of the invention.

The invention is, additionally to the following examples and the above general description, insofar as may be necessary for the man skilled in this specific art, described by means of one drawing.

The invention will thus be better understood and objects other than those set forth above will become apparent when consideration is given to this drawing, the description thereof and the described examples.

Brief description of the drawing

The sole figure shows schematically and in function block representation an apparatus as a preferred tool for manufacturing the inventive film material, the inventive TiO_2 or Ta_2O_5, and for performing the inventive method.

Description of the preferred embodiments

The inventive material is deposited by a magnetic field enhanced reactive plasma DC-sputter process, e.g. with processing

apparatus as known from the EP-A-0 347 567, the US-A-4 863 594, the DE-A-37 00 633, the US-A-4 693 805, the US-A-4 692 230 or the EP-A-0 501 016.

In a preferred mode and as described in the EP-A-0 508 359, according to the US application no. 07/865 116, deposited April 8, 1992, by the same applicant as the present application, the sputter deposition process is performed with a process working point in the transition mode between metallic mode and oxidic mode.

The EP-A-0 508 359 and its US counterpart application are thus integrated in the present description by reference, with respect to sputter deposition in the transition mode.

Today, there is used a plant for the inventive manufacturing of the inventive material, a BAK 760, of applicant with cylindric, rotated carrier for substrates to be coated and with a rectangular planar magnetron as DC-sputter source. The process is performed as described in the EP-A-0 508 359 and its US counterpart application in the transition mode, which is, per se, instable. The working point is stabilized in this instable mode by means of negative feedback control.

A gas feed line 3 abuts in a vacuum chamber 1. A working gas, which comprises a reactive gas or possibly a reactive gas mixture, is inlet into the chamber 1 via said gas feed line 3. In the case of the preferred production of TiO_2- or of Ta_2O_5-material, there is fed O_2 and e.g. Argon into the chamber 1. As schematically shown, there is provided a sputtering source 5, and a magnetic field $\overline{B}$ is applied in a tunnel-like pattern across the sputter source 5 or with lines of force extending in a bent manner from the sputter surface of the source 5 to and on adjacent parts of the vacuum chamber 1. In a preferred

mode, the sputter source 5 and the magnetic field associated thereto is realized by a magnetron, where the magnetic field $\overline{B}$ is kept stationary with respect to the surface being sputtered of the target or is moved relatively thereto.

From the sputtering source 5, the metal phase of the reaction product which is deposited on workpiece 9 is sputtered-off, thus, in the case of the preferred TiO_2 or Ta_2O_5, preferably a high percentage pure Ti- or Ta- metal.

Between the sputtering source 5, acting as a cathode, and an anode 7, there is generated a plasma discharge PL by means of a DC signal generator 11. The DC generator 11 is in one preferred embodiment coupled to the electrodes 7 and 5, latter defining the plasma discharge area, via a discharge control unit 13, as shown in the figure in a dashed manner. The unit 13, if provided, comprises a control input E and connects the electric tabs to the said electrodes 7 and 5 with a predetermined repetition rate, according to a repetition frequency f_r, and for respectively predetermined time spans by a low ohmic current path, which latter is realized, as an extreme, as a short circuiting current path.

The values of the entities τ and f_r may be stationarily set. Thereby, occurrence of stochastically time and position distributed arcing, as may occur due to deposition of electrically isolating depositions on the sputter surface of sputter source 5, may thereby be monitored. The rate of appearance of such arcing and/or arcing intensity is monitored with a sensor 15, the output signal thereof being compared at a comparator unit 17 with a predetermined rated rate value and/or intensity value. According to the result of the comparison at the unit 17, a negative feedback adjustment is performed on the time-span τ of low ohmic connection of the tabs to the electrodes 5

and 7 and/or of the repetition rate according to f_r, which adjustment is performed via control input E.

If arcing occurs too frequently in the chamber 1 and/or too intensively, the time-span τ and/or the repetition rate f_r are increased in negative feedback control manner, so as to reduce said arcing frequency and/or intensity.

By means of low ohmic interconnection at the unit 13, one counteracts deposition of charged particles on electrically isolating depositions, especially on the sputtered-off surface (target surface) of sputtering source 5.

Instead of monitoring arcing as a measured value for negative feedback control, it is absolutely possible, if at all unit 13 is provided, to measure the current which flows through the low ohmic current path intermittently installed at unit 13 or its time-course as a measured negative feedback control value to be compared with a rated value.

With a plant operated in the transition mode, as described in the EP-A-0 508 359 and its corresponding US application, and without provision of unit 13 of the figure, the following materials were produced as follows:

<u>Vacuum chamber</u>:	Diffusion pumped cubic chamber with 5" x 25" target, planar magnetron, target material of 99,99% metal, target to substrate distance 7cm, rotating substrates, substrate: Herasil (trademark).

1st example:

TiO_2	(a)	(b)
Electric power:	10kW	6kW
Ar pressure:	8E-4mbar	8E-4mbar
Ar flow:	70sccm	71sccm
O_2 partial pressure:	1,5E-4mbar	1,8E-4mbar
O_2 flow:	38,1sccm	28sccm
Ti intensity:	20%	24%
Target voltage in metallic mode:	-595V	-595V
Target voltage at processing working point:	-560V	-550V
Layer deposition rate:	1Å/sec	0,25Å/sec

Results:

Refractive index for light of a wave-length of 633nm:	2,42	2,42
applied as optical waveguiding layer with a thickness of:	75,5nm	112nm
Optical loss at 633nm in the TM_0-mode:	0,77dB/cm	0,6dB/cm
Substrate temperature:	≤ 70°C	≤ 70°C

2nd example:

Ta_2O_5:

Electrical power:	6kW
Ar pressure:	2E-3mbar
Ar flow:	50sccm
O_2 partial pressure:	8E-4mbar
O_2 flow:	50sccm

<u>Results</u>:

Refractive index at 633nm:	2,11
applied as optical waveguiding layer with a thickness of:	91,8nm
Optical loss in the TM_0-mode at a wave-length of 633nm	0,7dB/cm
Substrate temperature:	$\leq 70^{\circ}C$

3rd example:

Production of TiO_2 with provision of unit 13 according to the figure:

Electrical power:	5kW
Ar pressure:	3E-3mbar
Ar flow:	38,23sccm
O_2 partial pressure:	1,2E-3mbar
O_2 flow:	36sccm
Ti intensity:	26%
Target voltage in metallic mode:	-630V
Target voltage at processing working point:	-554V
Frequency of intermittent operation at unit 13:	43kHz
Deposition rate:	0,94Å/sec

Results:

Applied as optical waveguiding
layer with a thickness of: 89,2nm

Optical losses at light with
a wave-length of 633nm in
the TM_0-mode: 0,7dB/cm

As a conclusion, the inventors believe that a further optimized realization of the present invention will lead to optical losses as specified of 0,3dB/cm at the most.

Claims:

1. Optical film material of a metal oxide being deposited by reactive magnetic field enhanced DC-sputtering from a metallic target and having optical losses of 15dB/cm at the most for a wave-length of light of 633nm.

2. The optical film material of claim 1, said optical losses being 4dB/cm at the most.

3. The optical film material of claim 1 being TiO_2, said optical losses being 1,5dB/cm at the most.

4. The optical film material of claim 1, said metal oxide being Ta_2O_5 and said optical losses being 3dB/cm at the most.

5. The optical film material of claim 1, said optical losses being 1,5dB/cm at the most.

6. The optical film material of claim 1, said optical losses being 0,7dB/cm at the most.

7. The optical film material of claim 1, said optical losses being 0,3dB/cm at the most.

8. The optical film material of claim 1, said metallic target being made of the metal of said metal oxide.

9. The optical film material of claim 1 being deposited by time intermittent reactive magnetic field enhanced DC-sputtering.

10. The optical film material of claim 1 being deposited with a deposition rate of 0,5Å/sec at the minimum.

11. The optical film material of claim 1 being deposited at a deposition rate of 0,9Å/sec at the minimum.

12. The optical film material of claim 1 being subjected to a deposition temperature of 150°C at the most.

13. The optical film material of claim 1 being deposited at a deposition temperature of 100°C at the most.

~~14. The optical film material of claim 1 being deposited at a~~ deposition temperature of 70°C at the most.

15. A TiO_2 having optical losses of 1,5dB/cm at the most for a wave-length of light of 633nm.

16. TiO_2 according to claim 15, wherein said optical losses are 0,7dB/cm at the most.

17. TiO_2 according to claim 15, wherein said optical losses are 0,3dB/cm at the most.

18. Ta_2O_5, wherein optical losses for light of the wave-length of 633nm are 3dB/cm at the most.

19. Ta_2O_5 of claim 18, wherein said optical losses are 1,5dB/cm at the most.

20. Ta_2O_5 of claim 18, wherein said optical losses are 0,7dB/cm at the most.

21. Ta_2O_5 of claim 18, wherein said optical losses are 0,3dB/cm at the most.

22. An optical layer made of an optical layer material of a

metal oxide being deposited by reactive magnetic field enhanced DC-sputtering of a metallic target and having optical losses of 15dB/cm at the most for light of a wave-length of 633nm.

23. The optical layer of claim 22 being of TiO_2, said optical losses being 1,5dB/cm at the most.

24. The optical layer of claim 22, said material being Ta_2O_5, said optical losses being 3dB/cm at the most.

25. The optical layer of claim 22 in an optical multi-layer with at least one optical layer of lower refractive index material and at least one optical layer of higher refractive index material, said optical layer deposited by said reactive magnetic field enhanced DC-sputtering being said higher refractive index material layer.

26. The optical layer of claim 22 being an optical wave-guiding layer, said optical losses being valid in a TM-monomode.

27. The optical layer of claim 22 being an optical wave-guide layer, said optical losses being valid for a TM_0-mode.

28. The optical layer of claim 22 being a substantial flat optical wave-guiding layer.

29. A method for producing a layer of a metal oxide with optical losses of 15dB/cm at the most for light with a wavelength of 633nm, comprising magnetic field enhanced reactive DC-sputtering of said layer.

30. The method of claim 29, comprising the step of magnetic field enhanced reactive DC-sputtering from a metallic target.

31. The method of claim 29, comprising the step of performing said magnetic field enhanced reactive sputtering in the oxide mode.

32. The method of claim 29, comprising the steps of performing said reactive magnetic field enhanced DC-sputtering in the instable transition mode and stabilizing said sputtering in said transition mode.

33. The method of claim 29, comprising the step of performing said magnetic field enhanced reactive DC-sputtering in an intermittent manner.

34. The method of claim 33, thereby performing said sputtering intermittently with a frequency of 30kHz at the most.

35. The method of claim 33, thereby performing said intermittent sputtering at a frequency of 20kHz at the most.

36. The method of claim 29, thereby performing said magnetic field enhanced reactive DC-sputtering by magnetron sputtering.

37. The method of claim 29, comprising the step of sputter-depositing one of TiO_2 and of Ta_2O_5.

38. The method of claim 29, thereby producing an optical wave-guiding layer.

39. The method of claim 29, thereby producing said layer with said optical losses of 4dB/cm at the most.

40. The method of claim 29, comprising the step of depositing TiO_2, said losses being 1,5dB/cm at the most, or comprising the st p of depositing a Ta_2O_5-layer, said losses being 3dB/cm at

the most.

41. The method of claim 40, comprising the step of depositing said layers with said optical losses of 1,5dB/cm at the most.

42. The method of claim 40, comprising the step of depositing said layers with said optical losses being 0,7dB/cm at the most.

43. The method of claim 40, comprising the step of depositing said layers with said optical losses being 0,3dB/cm at the most.

44. The method of claim 29, comprising the step of applying between said target and a counter electrode a DC-current source and intermittently connecting said counter electrode and said target by a current conductor of reduced resistance.

45. The method of claim 44, comprising the steps of measuring at least one of the current through said current path of reduced resistance and of monitoring arcing during layer deposition as a measured control value and comparing said measured value with a rated value, thereby adjusting a repetition rate of said installing said current path of reduced resistance as a function of comparison result.

46. The method of claim 29, comprising the step of depositing said material at a deposition rate of 5Å/sec at minimum.

47. The method of claim 29, comprising the step of depositing said material at a deposition rate of 0,9Å/sec at minimum.

48. The method of claim 29, thereby maintaining a substrate on which said material is deposited during deposition of said

material at a temperature of 150°C at the most.

49. The method of claim 29, thereby maintaining a substrate on which said material is deposited during said deposition at a temperature of 100°C at the most.

50. Optical film material of a metal oxide substantially as herein described.

51. TiO_2 substantially as herein described with ~~reference to the first and third example.~~

52. Ta_2O_5 substantially as herein described with reference to the third example.

53. An optical layer made of an optic layer material of a metal oxide substantially as herein described.

54. A method for producing a layer of a metal oxide substantially as herein described with reference to, and as shown in, the accompanying diagrammatic drawing.

Patents Act 1977 Examiner's report to the Comptroller under Secti n 17 .'he Search report) -27-	Application number GB 9405709.8
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Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI, CLAIMS	Documents considered relevant following a search in respect of Claims :- 1-54

Categories of documents

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Category	Identity of document and relevant passages		Relevant to claim(s)
X	EP 0567954 A1	(CENTRAL CLASS) see especially Example 1	1,29
X	EP 0430229 A2	(APPLIED MATERIALS) see especially Claim 1; column 5 lines 36-39	1,4,29
X	US 5295220	(SCHOTT) see especially Example 1	1,29
X	US 5292417	(BALZERS) see especially Claim 1; page 15 lines 23-33	1,29
X	US 5169509	(LEYBOLD) see especially Claim 1; column 2 lines 20-35	1,3,4,29
X	US 5126033	(LEYBOLD) see especially Claim 1; column 1 lines 30-40	1,3,29
X	US 5026471	(LEYBOLD) see especially Claim 1; column 5 lines 7-10	1,3,4,29
X	US 4512864	(PPG) see especially Example 1	1,29
X	US 4497700	(FLACHGLAS) see especially Example 1; Claim 5	1,29

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